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July 18, 2017

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**Conceptual Site Model (CSM) for Poly- and Perfluoroalkyl Substances (PFAS)
Chemours Chambers Works
Deepwater, New Jersey**

Dear Ms. Pavelka:

Attached please find the Conceptual Site Model (CSM) for Poly- and Perfluoroalkyl Substances (PFAS) for the Chemours Chambers Works Complex in Deepwater, New Jersey. The CSM was prepared in response to an April 6, 2016 request from NJDEP. The request specified that a CSM be created that included the identification and characterization of all former and/or current sources of PFAS at Chambers Works as well as all former and/or current modes of migration, pathways and receptors. This CSM was created in general accordance with the NJDEP Technical Guidance for the Preparation and Submission of a CSM (NJDEP, 2011). The areal scope of the CSM includes the Chambers Works Complex, the adjoining Delaware River, and surrounding off-site areas.

Also included in this CSM are data from an ongoing residential drinking water well program. These data indicate the presence of PFAS in off-site groundwater, at times exceeding NJDEP and/or U.S. Environmental Protection Agency (EPA) criteria for perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), or perfluorononanoic acid (PFNA). While the CSM supports conclusion that air emissions from the site contribute to these detections, off-site sources of PFAS unrelated to the site may also add to these detections as the variability in PFAS constituents detected and the variable nature of the observed concentrations do not support a single point of origin in all cases. However, Chemours is actively working with NJDEP and EPA to continue to investigate, remediate, and address potential drinking water exposure by offering to treat off-site drinking water for PFAS if criteria are exceeded.

Chemours is submitting three hard copies of the report and one electronic version on a CD to both NJDEP and EPA.

If you have any questions or would like to discuss the CSM document further, please email me at Andrew.S.Hartten@chemours.com or call me at 302-773-1289.

Sincerely,

Andrew S. Hartten
Project Director, Chambers Works
DuPont Corporate Remediation Group

cc: Sameh Abdellatif, EPA Region 2 (three hard copies and one CD)
Chambers Works File

Chemours Chambers Works
Conceptual Site Model (CSM) for Poly- and Perfluoroalkyl Substances (PFAS)

CERTIFICATION I

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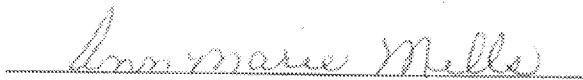


Andrew S. Hartten
Chemours Corporate Remediation Group
Principal Project Manager

July 17, 2017

Date

WITNESSED THIS 17th DAY OF July, 20 17



Notary Public



Conceptual Site Model (CSM) for Poly- and Perfluoroalkyl Substances (PFAS)

Chemours Chambers Works
Deepwater, New Jersey

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The Chemours Company

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Acronym List

Acronym	Explanation
µg/kg	Microgram per Kilogram
µg/L	Microgram per Liter
bgs	Below Ground Surface
CATT	C8 Assessment of Toxicity Team
cfs	Cubic Feet per Second
CRG	Corporate Remediation Group
CSM	Conceptual Site Model
DRBC	Delaware River Basin Commission
EPA	U.S. Environmental Protection Agency
GAC	Granular Activated Carbon
GWQS	Ground Water Quality Standards
HA	Health Advisory
IWS	Interceptor Well System
lbs/day	Pounds per Day
mg/kg	Milligram per Kilogram
mgd	Million Gallons per Day
ND	Not Detected
NJDEP	New Jersey Department of Environmental Protection
NJGWIIA	New Jersey Groundwater Class IIA Standards
NJPDES-DGW	New Jersey Pollutant Discharge Elimination System Permitting Discharge to Groundwater
NJSWQS	New Jersey Surface Water Quality Standards
NQ	Not Quantifiable
OM&M	Operations Maintenance and Monitoring
PAR	Preliminary Assessment Report
PFAS	Poly- and Perfluoroalkyl Substances
PFDA	Perfluorodecanoic Acid
PFHpA	Perfluoroheptanoic Acid
PFHxA	Perfluorohexanoic Acid
PFNA	Perfluorononanoic Acid
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane Sulfonate
PFPeA	Perfluoropentanoic Acid
ppm	Part per Million
PQL	Practical Quantitation Limit
PTFE	Polytetrafluoroethylene
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SET	Secure Environmental Treatment
SPB	Sheet-Pile Barrier
WWTP	Wastewater Treatment Plant

Executive Summary

AECOM, on behalf of the Chemours Company (Chemours), has prepared this Conceptual Site Model (CSM) for Poly- and Perfluoroalkyl Substances (PFAS) for the Chambers Works Complex (the site) located in Deepwater, New Jersey, as requested by New Jersey Department of Environmental Protection (NJDEP) in an April 6, 2016 letter to Chemours. The CSM presented herein was created in general accordance with the NJDEP Technical Guidance for the Preparation and Submission of a CSM (NJDEP, 2011). The areal scope of the CSM includes the Chambers Works Complex, the adjoining Delaware River, and surrounding off-site areas.

The purpose of this CSM is to identify sources of PFAS and potential migration pathways that may have resulted in detections of PFAS in off-site environmental media receptors identified in this CSM as off-site surface water, sediment, and residential well water. As such, this CSM incorporates PFAS data associated with soil, sediment, surface water, groundwater, treatment plant effluent, and stack and vent emissions collected at and around the site since 2003 to construct the CSM framework.

A potential fourth source for PFAS detections should be recognized. This includes consumer and industrial products that contain PFAS, such as windshield wiper fluid, cosmetic products, and fire extinguishers. These products are not associated with the site but are frequently present in homes and businesses and could also contribute to the detections of PFAS in off-site environmental media. Although the possibility of these sources is acknowledged, no measured data were included in the development of this CSM.

Three primary sources of PFAS have been identified at Chambers Works: PFAS [e.g., perfluorooctanoic acid (PFOA)] were used or unintentionally created during the manufacturing of fluoroelastomers and fluorotelomers starting in the 1960s; PFAS were associated with breakdown constituents related to precursor compounds (e.g. fluorotelomer alcohols); and liquid wastes that potentially contained PFAS were brought to Chambers Works for treatment at the site's Wastewater Treatment Plant (WWTP). Since 2003, the use of PFOA has been reduced at Chambers Works. Chambers Works has continued to implement reduction programs that have resulted in an overall 99% reduction in PFOA emissions since 2000.

Migration pathways for the movement of PFAS from sources to off-site environmental media receptors include air emissions and downwind movement of PFAS from stacks and vents during manufacturing processes; discharge of a treated effluent that contains PFAS from the WWTP through two permitted outfalls to the Delaware River; stormwater runoff that contains PFAS and discharges through outfalls to Salem Canal; and to a lesser extent, groundwater containing PFAS that discharges through the shallow aquifer to the Delaware River. However, a sheet pile barrier (SPB) was installed along the Salem Canal, which contains groundwater on-site and limits the discharge from the shallow aquifer to off-site surface water. Discharge will be reduced with the installation of the final section of the SPB engineering control along the Delaware River in the manufacturing area in 2017. Because groundwater flow is controlled by the site Interceptor Well System (IWS) and the SPB controls groundwater discharge along the southwestern perimeter, there is no migration pathway through groundwater to off-site well locations.

Several investigations have been completed and have adequately characterized PFAS in the media investigated to develop this CSM. PFAS have been detected in soil and groundwater at the Chambers Works Complex. PFAS were detected most frequently and at the highest concentrations in shallow groundwater samples closest to known site process areas that used PFAS. Concentrations decrease with increasing depth and distance from known process buildings.

Detections of PFAS in surface water in the Salem Canal adjacent to the site indicated little difference from upgradient background locations. For the Delaware River, PFAS concentrations were detected in surface water adjacent to the site. For sediment samples collected from the Delaware River and Salem Canal, higher PFAS detections were noted in samples collected near stormwater and permitted effluent discharge locations.

Off-site groundwater investigations in 2007, 2009, 2010, 2014, and 2016, as well as an ongoing residential drinking water well program, indicate the presence of PFAS in off-site groundwater, at times exceeding NJDEP and/or EPA criteria for PFOA, perfluorooctane sulfonate (PFOS), or perfluorononanoic acid (PFNA). While air emissions from the site contribute to these detections, off-site use of PFAS-containing products unrelated to the site may also add to these detections as the variability in PFAS constituents detected and the variable nature of the observed concentrations does not support a single point of origin in all cases. However, Chemours is actively working with NJDEP and EPA to continue to investigate and remediate, and to address potential drinking water exposure by offering to treat off-site drinking water for PFAS, if criteria are exceeded.

1.0 Introduction

AECOM, on behalf of The Chemours Company (Chemours), has prepared this Conceptual Site Model (CSM) for Poly- and Perfluorinated Substances (PFAS) for the Chambers Works Complex (the site) located in Deepwater, New Jersey (see Figure 1). PFAS are a diverse group of compounds that are resistant to heat, water, and oil. PFAS have been used in both industrial applications and consumer products such as carpeting, apparels, and fire-fighting foams. At Chambers Works, PFAS and precursors to PFAS (i.e., fluorotelomer alcohols) have been used in the production of fluoroelastomers, fluorotelomers, and have also been unintentionally created within manufacturing processes and waste streams.

As described in the New Jersey Department of Environmental Protection (NJDEP) *Technical Guidance for the Preparation and Submission of a CSM* (NJDEP, 2011), a CSM is a written and/or illustrative representation that describes sources, migration pathways, and potential impacts of contamination (in soil, air, groundwater, surface water, and/or sediments) to human and/or ecological receptors. The CSM presented herein was developed in general accordance with the aforementioned guidance as requested by NJDEP in an April 6, 2016 letter.

This Chambers Works PFAS CSM includes the following components: identification of potential source(s), characterization of media and extent of contamination, identification of all potential and confirmed migration pathways of the contaminants of concern for the investigation area, and identification of general off-site receptors (i.e., surface water, sediment, and drinking water).

1.1 Purpose and Objective

The purpose of this CSM is to provide a written and illustrative representation of the potential fate and transport of PFAS from on-site sources to on-site and off-site environmental media. As such, this CSM incorporates soil, sediment, surface water, groundwater, treatment plant effluent, and stack and vent emission PFAS data collected at and around the site since 2003. In addition, this CSM includes results of an ongoing off-site residential drinking water sampling program.

The objectives of this report are as follows:

- Identify known and potential on-site and off-site PFAS sources.
- Describe PFAS migration pathways.
- Present the comprehensive database of PFAS concentrations detected in the environmental media at the site and surrounding areas.

1.2 Report Structure

The remainder of this report is organized as follows:

- Section 2.0 describes the site environmental setting, including land uses on-site and surrounding the site.
- Section 3.0 presents information pertaining to historical and current use of PFAS at the site.

- Section 4.0 presents the PFAS environmental data collected during on-site and off-site investigations.
- Section 5.0 details PFAS migration pathways.
- Section 6.0 summarizes the key findings of the presented CSM components.
- Section 7.0 lists the references cited in this report.

2.0 Site Background

This section presents background information pertaining to the site setting, the surrounding land use, site groundwater conditions and containment, and surface water features.

2.1 Site Setting

The 1,455-acre site is located on the northwestern side of Salem County New Jersey, north of the Delaware Memorial Bridge and occupies approximately 2.7 miles of shoreline on the tidal Delaware River from Helms Cove to the Salem Canal (see Figure 1). The site consists of the former Carneys Point Works area, which manufactured explosives prior to 1978, and the currently active manufacturing area. The site is secured by a fence and is monitored 24 hours, 7 days a week by security personnel.

The Chambers Works Complex produces various products and intermediates. The manufacturing area of the site includes Performance Chemicals, which makes intermediates, and Secure Environmental Treatment (SET), which treats on-site wastewater at the site's wastewater treatment plant (WWTP). Manufacturing and utility tenants include DuPont Performance Elastomers, Aramids Intermediates, the Cogeneration Plant, and Praxair. The Cogeneration Plant is a utility tenant producing steam and electricity for the site and the regional electrical grid. Praxair is a utility tenant producing nitrogen for the site and regionally for other customers.

2.2 Surrounding Land Use

The site is located adjacent to the Delaware River, which extends along the entire western side of the site. The Salem Canal, Interstate 295, and the Delaware Memorial Bridge are located due south of the site. Further south are light industrial areas, including the Calpine Deepwater Energy Center (formerly Atlantic City Electric), residential areas, and recreational areas. North and east of the site are small businesses and residential neighborhoods.

2.3 Surface Water

The primary surface water features in the vicinity of Chambers Works consists of the following (see Figure 1).

- Delaware River
- Salem Canal
- Bouttown Creek and Henby Creek
- B Basin

Each of these features is described in more detail below.

2.3.1 Delaware River

The Delaware River forms the western property boundary of the site. The portion of the Delaware River adjacent to the site lies within the Delaware River Basin Commission (DRBC) Interstate Water Quality Management Zone 5, which extends from river mile

48.1 near Middletown, Delaware, upstream to river mile 78.7, near the Pennsylvania-Delaware border. Zone 5 designated uses include navigation, commercial shipping, and recreation. This portion of the river has been influenced by historical and current industrialization, as well as intensive upstream urban development associated with Philadelphia, Pennsylvania, and Camden, New Jersey. The flow of the Delaware River is reported in the range from 3,000 to 100,000 cubic feet per second (cfs), with an average flow rate of approximately 11,000 cfs, and a tidal amplitude of approximately 6 feet between high and low tides.

Adjacent to the site, the Delaware River is generally considered an oligohaline environment. An oligohaline environment represents the transitional zone between the tidal freshwater and estuarine environments. Salinities in this zone are controlled by the input of freshwater from the upper watershed and are tidally, seasonally, and annually variable. The Delaware River is not used for drinking water purposes in Zone 5 due to its brackish water quality and the industrial nature of the area. Chambers Works has a river water intake that is permitted to withdraw up to 13 to 22 million gallons per day (mgd) for site use, such as brine production and noncontact cooling water.

Chambers Works historically used one permitted outfall to the Delaware River. Outfall DSN001 was operated as the site's main outfall for wastewater discharge. This discharge included stormwater collected on-site, as well as treated SET wastewater. Starting in 2011, a second outfall, DSN002, was added. Historical wastewater outfalls, current stormwater outfalls, and the permitted outfalls have been identified from existing site plans and were or are potential migration pathways from the site to the Delaware River. Site-related outfalls are discussed further in Sections 4.0 and 5.0.

2.3.2 Salem Canal

The Salem Canal traverses the southern portion of the site for approximately 2,000 feet and is a freshwater, manmade canal that is approximately 7,000 feet long and approximately 200 feet wide. The Salem Canal was originally hand dug in 1872 to a depth of between 12 and 14 feet below ground surface (bgs). The Munson Dam was constructed in 1933 isolating the freshwater of the Salem Creek from the brackish tidal water of the Delaware River. Prior to the construction of the dam, the canal was a tidal water body connecting the Delaware River to the tidal wetlands of Salem Creek. Although Salem Canal is not used by the local community as a source of drinking water, Chambers Works has a water allocation permit to withdraw up to 5 to 7 mgd from the Salem Canal for plant use.

Chambers Works currently operates and has historically operated stormwater outfalls along the Salem Canal. Historical and current stormwater outfalls have been identified from existing site plans and were or are potential migration pathways from the site to the Salem Canal. Site-related outfalls are discussed further in Sections 4.0 and 5.0.

2.3.3 Bouttown Creek and Henby Creek

Bouttown Creek originates east of the site near the town of Carneys Point. Stormwater from Carneys Point Township enters the creek off-site and is regulated by a township-operated pump house located near the Chemours property line. Prior to 1974, Bouttown Creek discharged to the north through a sluice gate to the Delaware River. In 1974, the original point of discharge in Bouttown Creek was cut off and filled; flow in Bouttown Creek was then diverted to Henby Creek to the south via a constructed channel. Henby Creek flow is controlled by a sluice gate, and water discharges to the Delaware River

during low tide. Bouttown and Henby Creeks are flanked by low-lying wetlands. Neither of these creeks is used as a water source for the site.

2.3.4 B Basin

B Basin is an approximately 7.3-acre unlined basin used to manage stormwater and non-contact cooling water for the plant. The basin is located within active process areas of the site. The basin elevation is controlled by pumps, and the stormwater is mixed with treated wastewater from SET and is then discharged to the Delaware River through DSN001 and DSN002.

2.4 Groundwater

The Chambers Works site is underlain by a vertically stacked sequence of alternating coarser-grained (sand and gravel) and finer-grained (silt and clay) units that generally act as aquifers and aquitards, respectively. These units are the primary features that control groundwater storage and movement at the site. The primary hydrogeologic units are identified, from shallow to deep, by a series of letters from A to F. These include the designation of a discontinuous A zone (most shallow) and aquifers B through F with intervening aquitards described by the letter designations of the bounding aquifers (i.e., the C/D aquitard lies between the C and D aquifers).

Groundwater flow across the site has both horizontal and vertical flow components. Saturated groundwater in the A zone is not considered to be laterally extensive, and A zone groundwater either discharges to surface water where not controlled by passive flow barriers, or recharges the underlying B aquifer. Groundwater flow in the B aquifer is downward to the deeper C and D aquifers where the B/C aquitard is thin or absent, or horizontal to the surface water of the Salem Canal and Delaware River. Since 2009, a series of sheet-pile barriers (SPB) have been constructed to control the horizontal discharge from the A zone and B aquifer to the adjoining surface water. To date, the southern and southwestern extents of the B aquifer along the Salem Canal and the southwestern to western boundaries of the B aquifer along the Delaware River have been controlled by 4,618 feet of SPBs installed vertically from ground surface down to the B/C aquitard. Currently, a 2,233-foot-long length of SPB remains to be installed adjacent to the Delaware River along the northern most section of the manufacturing area. This construction is scheduled to be completed in the summer of 2017. When completed there will be no flow of groundwater from the A zone or B aquifer to surface water.

As stated above, some groundwater flow in the B aquifer is downward to the C and D aquifers. Groundwater flow in the C and D aquifers is hydraulically connected and would flow horizontally off-site if not controlled by the site interceptor well system (IWS). The D/E aquitard is a relatively thick, continuous, low permeable unit of regional significance that isolates the underlying E aquifer from the groundwater flow of the overlying aquifers. E aquifer groundwater is pumped and contained. There is a downward gradient from the D to the E aquifer, so leakage through the D/E aquitard can occur; however, the leakage is expected to be minimal due to the low vertical hydraulic conductivity and significant thickness of the D/E aquitard.

The IWS pumps a minimum average of 1.0 mgd from four primary and three backup recovery wells in the C and D aquifers and has been in operation since the 1970s. The IWS creates a capture zone that contains all on-site C and D aquifer groundwater. This

groundwater capture system, and the SPB, prevents the migration of groundwater off-site.

3.0 PFAS Background Information and Sources

This section presents PFAS background information; PFAS sources at Chambers Works; a summary of PFAS reduction programs at the site; and PFAS sources off-site unrelated to Chambers Works.

3.1 Poly- and Perfluoroalkyl Substances Background

PFAS is a class of emerging contaminants with over 3000 compounds that have been released into the environment from industrial processes, as well as from the use of PFAS-containing products. PFAS have been used globally since the mid-1960s. PFAS compounds contain carbon chains of various lengths and carbon-fluorine bonds. Table 1 provides a list of PFAS compounds analyzed for at the site in the investigations described in Section 4.0 although not all of these PFAS were analyzed for in each investigation. Table 1 also provides information pertaining to compound abbreviation and associated carbon length.

Carbon binds strongly with fluorine, which contributes to PFAS strength, durability, heat-resistance, and stability. These properties make PFAS useful for a wide range of industrial applications, as well as the manufacture of consumer goods including cleaners, textiles, leather, paper and paints, fire-fighting foams, and wire insulation. PFAS are also soluble in water and can enter environmental media through industrial releases to air and water, discharges from wastewater treatment plants, stormwater runoff, release of firefighting foams, and land application of contaminated biosolids.

PFAS have also been identified as a byproduct associated with the breakdown of fluorotelomer alcohol in the atmosphere and soil. Fluorotelomer alcohols, which are manufactured and used at the site, can be released into the environment through air and wastewater emissions. Once released, fluorotelomer alcohol may react or be oxidized in the atmosphere and/or in soil with chlorine atoms, oxygen molecules or photochemically generated hydroxyl radicals (Houtz et al., 2012), creating PFAS compounds as an oxidation byproduct.

The high solubility, low volatility, and resistance of PFAS to both chemical and biological degradation (Pancras et al., 2016) has led to the presence and persistence of PFAS in the environment. Depending on the length of the carbon chain, PFAS may sorb to naturally occurring solid organic carbon particles present in soil or sediment. Longer carbon chain PFAS tend to have a higher sorption potential, whereas shorter carbon chain PFAS have a lesser sorption potential (Pancras et al., 2016). Because PFAS are generally considered to be recalcitrant to biodegradation via naturally occurring microorganisms in water, soil, or sediment and can have a low potential for sorbing to naturally occurring carbon, PFAS have the potential to migrate within the environment.

3.2 PFAS Source Areas at Chambers Works

PFAS were used [e.g., perfluorooctanoic acid (PFOA)], manufactured (e.g., fluorotelomer alcohols), or unintentionally created in the production of fluoroelastomers and fluorotelomers at Chambers Works. In addition, PFAS-containing liquid waste from off-site sources was treated at the site WWTP. Associated residual waste sludge was disposed of in on-site landfills; treated effluent was discharged through the permitted WWTP outfall to the Delaware River.

One of the initial PFAS investigations at Chambers Works site involved the assessment of the PFAS PFOA at the site [DuPont Corporate Remediation Group (CRG), 2005]; PFOA was used at the site as a manufacturing polymerization aid. This PFOA assessment included a review of site records along with interviews of key employees.

During the historical records review, PFOA was determined to potentially be associated with the following process areas at the Chambers Works Complex (see Figure 2):

- Fluoroelastomer Manufacturing Area
- Fluorotelomer Manufacturing Area
- Jackson Laboratory Area
- Chambers Works WWTP
- Chambers Works Performance Chemical Areas

Historical PFAS information pertaining to these process areas are provided below. Table 1 lists PFAS compounds analyzed for in Chambers Works PFAS investigations. Table 2 presents a Chambers Works PFAS process summary, and Table 3 lists PFAS-related products and uses.

3.2.1 Fluoroelastomers Manufacturing Area

PFOA was used as a polymerization aid in the manufacturing of perfluoroelastomers and specialty fluoroelastomers, which began at Chambers Works in the late 1950s in Building 1163. PFOA was also used as a processing aid in the manufacturing of standard fluoroelastomers at Chambers Works in Building 745.

By the end of 2013, as part of the PFAS reduction program discussed in Section 3.3, the use of PFOA was discontinued in all perfluoroelastomer manufacturing processes.

3.2.2 Fluorotelomer Manufacturing Area

Fluorotelomer use and manufacture at Chambers Works began in 1962 in Buildings 1050 and 1205. The initial process development, scale-up, market development, and initial manufacturing, were conducted in these buildings. In 1967, the fluorotelomer production was moved to Buildings 234 and 1156, known as the ZI Area. Intermediates from the ZI Area are distributed to other locations, including Building 185, Building 788, Building 888, Building 115 (EO Center), and Buildings 1050 and 1205 for the manufacture of final products.

Fluorotelomers are not made with PFAS, nor is PFAS added during fluorotelomer manufacture. PFAS is present in trace quantities as an unintended by-product in portions of the fluorotelomer manufacturing process. The presence of PFAS in fluorotelomer intermediates, while low, is highly variable from not quantifiable¹ (NQ) to parts per million (ppm) (AECOM, 2015). The site's transition to the use of short-chain fluorotelomer chemistry, which cannot breakdown to PFOA, was completed in December 2014.

¹ Not Quantifiable = detected at a concentration between the limit of detection and the limit of quantification.

3.2.3 Jackson Laboratory Area

Jackson Laboratory provided analytical services, and research and development to the Chambers Works Complex. While there are no records of bulk use of PFAS in this area, PFAS presence may have been limited to quantities in samples analyzed at the area or through research and development (see Table 2). The Jackson Laboratory was shut down and its operations were moved to the Pederson Building beginning in late 2008.

3.2.4 Chambers Works WWTP Area

Prior to 1975, site buildings located at the interior of the site sent wastewater to the nearest ditch for conveyance to the site wastewater settling basin; water within the settling basin discharged to the Delaware River. For buildings adjacent to the Delaware River, wastewater entered the nearest ditch and flowed directly to the river through the nearest outfall location (DuPont CRG, 2006b).

In 1975, a WWTP was constructed at the Chambers Works site. The WWTP was constructed to treat wastewater associated with on-site process buildings. Prior to the 1990s, wastewater was transferred to the WWTP via a series of wood-lined culverts and ditches, which could have released PFAS during conveyance. In the early 1990s, as part of the site's efforts to decrease potential impacts to the environment, a series of enclosed overhead conveyance pipes were constructed to replace the wood-lined culverts and ditches. The installation of the overhead transfer system removed the potential for an on-going wastewater release to the environment.

Liquids transferred to the Chambers Works WWTP for treatment include on-site process wastewater streams, landfill leachate, and groundwater from the IWS. Until March 2012, the WWTP also accepted commercial wastewater streams and wastewater streams from other Chemours facilities for treatment. A small portion of these commercial streams contained ppm levels of PFAS according to the information evaluated for the PFOA Preliminary Assessment Report (PAR) (DuPont CRG, 2005). The PFAS associated with the WWTP could have been released during or after treatment via air, liquid, or as sludge. All commercial streams have been eliminated as part of PFAS reduction efforts, and PFAS from commercial wastewaters are no longer a contributor to PFAS in effluent from the WWTP.

Treated effluent from the WWTP that may contain PFAS is discharged through permitted outfalls DSN001 and DNS002 (after 2011). Hazardous sludge from the WWTP, which may contain PFAS, is placed in the on-site secure landfill (Secure C Landfill). The secure landfill cells are double-lined with a leachate collection system and leak detection system. Only Area 1 of this landfill is single-lined and in the past has leaked, but it was closed in 1979 and has a groundwater recovery system operating to contain and properly dispose of any leakage. Therefore, WWTP sludge potentially containing PFAS is properly contained and not a concern.

3.2.5 Chambers Works Performance Chemicals Areas

From 1999 to 2002, a PFOA recovery/purification process operated in Performance Chemicals West Building 1205, and material from this process was stored in Building 1050. The process purified approximately 50 batches and 60,000 pounds of PFOA during that time. All wastewater from this process was sent to the WWTP via the regional tank and overhead process sewer system.

Since 2014, a process to recycle iodide from material that contains PFAS has been operating at the site's Performance Chemicals East Building 115. This process was piloted in 2014 after successful trials showed no negative impact to the Chambers Works emission reductions program. The process was scaled up in March 2015 and continues to operate. Material from Chemours Washington Works is transported to Chambers Works to reclaim iodine (in the form of an iodide salt solution) from materials that contain longer chain PFAS. The reclaimed iodide solution is then sent to a third-party processor for further refinement before being sent back to Washington Works for reuse. After iodine removal at Building 115, the material remaining is sent to an off-site facility for incineration.

3.3 Chambers Works PFAS Load Reduction Programs Implemented

The Chambers Works complex has been reducing the release of PFAS and compounds that can convert to PFAS in the environment through process improvements and source elimination. In 2003, a comprehensive study was performed on the environmental emissions of PFOA from Chambers Works. The study assessed surface-water transport to the Delaware River, conducted air dispersion modeling of potential sources, and assessed concentrations in groundwater and surface waters adjacent to the site. The 2003 report (DuPont, 2003) showed that surface water and calculated fence-line air concentrations were below C8 Assessment of Toxicity Team (CATT; West Virginia Department of Environmental Protection) established 2002 screening levels for PFOA. In January 2005, Chambers Works implemented a sampling program to measure the effectiveness of the PFOA reduction efforts and to identify program areas that needed additional focus.

In January 2006, DuPont participated in the U.S. Environmental Protection Agency (EPA) 2010/15 PFOA Stewardship Program. Chambers Works was an important part of the DuPont commitment to reduce emissions of PFOA globally. By year end 2007, Chambers Works had reduced PFOA emissions from the site by 95%, three years ahead of the Stewardship Program's 2010 goal.

Chambers Works has continued to implement reduction programs through 2014, including installation of pre-treatment facilities, which resulted in an overall 99% reduction in PFOA emissions since 2000 based on production estimates (Andrew Hartten, personal communication, June 22, 2017). Some of the activities performed by the site to reduce the release of PFAS to the environment include the following:

- Early 1990s: Transitioned from an open process waste ditch to an overhead sewer system.
- Early 2000s: Enclosed handling/loading facilities to limit PFAS release to the environment.
- 2001: Discontinued use of PFOA in standard fluoroelastomers.
- 2003: Eliminated many PFOA-containing waste streams to the WWTP.
- 2004: Installed carbon treatment system to treat washwater and process cleanouts.
- 2012: Exited the commercial waste treatment business.
- 2013: Discontinued use of PFOA in all perfluoroelastomer manufacturing.

- 2014: Completed transition to short-chain fluorotelomer chemistry, which cannot breakdown to PFOA in the environment.

3.4 PFAS Sources Off-Site of Chambers Works

The off-site use and disposal of PFAS-containing products unrelated to Chambers Works could become off-site sources of PFAS to off-site environmental media. Some examples of PFAS associated products and materials that may be used or disposed of off-site by either residential property owners or by outside businesses include the following (Guo, 2009):

- Pre-treated carpeting
- Carpet care liquid treated carpeting
- Treated apparel
- Treated upholstery
- Treated home textiles
- Treated non-woven medical garments
- Industrial floor wax and wax removers
- Stone, tile, and wood sealants
- Membranes for apparel
- Food contact paper
- Dental floss/tape
- Thread sealant tape
- Polytetrafluoroethylene (PTFE) cookware

The off-site use or disposal of PFAS associated products/materials, or the washing of PFAS associated products/materials and subsequent disposal of graywater (either via discharge to ground surface or via septic system), could create a PFAS source that could migrate to off-site environmental media. A study of domestic drinking water wells (Schneider, 2016; Silentspring.org article) found that residential septic systems were the main source of contaminants to groundwater; contaminants detected in this study included perfluorooctane sulfonate (PFOS) and PFOA. Although specific information on local off-site sources and migration pathways are not known in detail for the area surrounding the Chambers Works site, it is important to acknowledge that these likely do exist and may be contributing to the concentrations of PFAS measured in off-site environmental media.

However, the following potential sources and associated release mechanisms are known to exist within or near the area encompassed by the investigative area discussed within this report:

- Airports, which can contain fire training areas that use PFAS-containing foams
- Fire station training centers that can use or historically used PFAS-containing foams
- Landfills and sewage treatment plants that may aerate and expose PFOA-waste materials, which can be released to the air

- Light industry, which may use PFAS-containing products, thereby possibly generating PFAS-containing wastewater discharge and air emissions

4.0 PFAS Environmental Data Set

The first environmental assessment of PFAS at the Chambers Works site was performed in March 2003 (DuPont, 2003). This investigation evaluated the potential presence of PFOA in air, surface water, and groundwater around Chambers Works and provided a snapshot characterization of PFOA presence at Chambers Works in 2003. Since 2003, PFAS has been investigated in various media located both on-site and off-site and are discussed in this section. This section summarizes PFAS data that were collected as part of these investigations, including their objectives and findings.

4.1 Screening Criteria

This CSM focuses on PFAS as the constituents of potential concern and their presence detected in environmental media. Various PFAS (Table 1) were analyzed for in the investigations of PFAS in on- and off-site environmental media. To evaluate the concentrations detected in air, soil, groundwater, surface water and sediment, the laboratory analytical data for each media should be compared to applicable established criteria. There are established PFAS screening criteria for groundwater. However, there are no established NJDEP or EPA Region 2 screening criteria for PFAS in air, surface water, sediments, or industrial soil.

A New Jersey Groundwater Class IIA (NJGWIIA) groundwater quality criterion of 0.01 microgram per liter ($\mu\text{g/L}$) has been established for PFNA, and PFNA is the only PFAS for which a NJGWIIA has been established. PFOA and PFOS do not have an established New Jersey Ground Water Quality Standard (N.J.A.C 7:9C). However, in the absence of an available groundwater standard, individual PFOA and PFOS concentrations in on-site groundwater were compared to EPA's 2016 Lifetime Health Advisory (HA) for PFOA and PFOS. When both PFOA and PFOS are detected in a location, the individual PFOA and PFOS concentrations and the sum of PFOA and PFOS concentrations were compared to the HA of 0.07 $\mu\text{g/L}$. EPA has not established health advisories for any other PFAS listed in Table 1.

In addition, as part of the assessment of PFOA results associated with off-site residential drinking water, the residential drinking water results were also compared to the NJDEP preliminary health-based guidance for PFOA in drinking water value of 0.04 $\mu\text{g/L}$. This additional comparison of results was completed based on an agreement between Chemours and NJDEP.

4.2 On-Site PFAS Data

This section presents the results of on-site investigations into the distribution of PFAS in various media. On-site media investigated included the following:

- Soil
- Groundwater
- Permitted outfalls
- Stormwater outfalls
- Air emissions

Results are presented in tabular form (see Tables 4 through 7) as well as on posting maps and figures (see Figures 3 through 8).

4.2.1 On-Site Soil

PFOA has been detected on-site in shallow soil near process buildings due to the use and handling of PFAS at the nearby buildings. As reported in the October 2006 Site Investigation Report for PFOA (DuPont CRG, 2006a) and in the June 2007 Site Investigation Report Addendum for PFOA (DuPont CRG, 2007a), 25 soil samples were collected from the zone beneath the gravel or macadam surface and above the shallow aquifer. The objective of this focused site investigation was to determine if PFOA was present in soil in areas where PFOA was associated with former or current activities. Of the 25 samples analyzed, there were 24 detections of PFOA (see Figure 3). Soil concentrations ranged from not detected² [ND; <0.00048 milligrams per kilogram (mg/kg)] to 2.8 mg/kg (see Table 4).

Although the origin of these detections was not discussed in the 2006 and 2007 reports, the presence of PFOA in soil adjacent to these buildings is likely due to the use and handling of PFAS in and near these buildings.

4.2.2 On-Site Groundwater

Prior to 2007, two investigations included PFOA analysis of groundwater samples (DuPont CRG, 2006a and 2007a). A PFOA monitoring program has been incorporated into the New Jersey Pollutant Discharge Elimination System Permitting Discharge to Groundwater (NJPDDES-DGW) monitoring program in 2007. Since then, PFOA and 12 additional PFAS have been analyzed in semi-annual groundwater samples from monitoring wells constructed in the A zone and the B, C, D, and E aquifers. Currently, there are 36 wells sampled: five in the Carneys Point Works area and 31 in the manufacturing area. The wells were selected to provide characterization of groundwater quality in the A zone and B through E aquifers along the site perimeter and in the area of former PFOA-related manufacturing operations. Results from the latest NJPDDES-DGW sampling (AECOM, 2017a) were used to evaluate the groundwater quality of the B through E aquifers with respect to PFAS (see Figures 4a through 4d). A summary table of on-site groundwater results is presented in Appendix A. Table 5 contains a statistical summary of on-site PFAS results by aquifer.

In 2013, a review of on-site groundwater data gaps related to PFAS sampling was included as part of the *Comprehensive Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report* (URS, 2014). Based on the data gap recommendations, a one-time sampling of 15 monitoring wells in the C and D aquifers for PFOA and PFOS was completed in February 2014. A summary of results associated with that one-time PFAS sampling event are shown in Figure 5.

Groundwater detections for PFOA, PFOS, and PFNA were compared to the screening criteria outlined in Section 4.1. The highest exceedance for on-site groundwater was for PFOA at G09-M01A with a concentration of 1,600 µg/L (see Figure 4a). G09-M01A was constructed in shallow groundwater adjacent to a sump at Building 1156, where PFOA was historically used.

² Not Detected = Not detected above the limit of detection as indicated in the associated tables and figures, as appropriate.

Evaluation of the data described above indicated the following:

- PFAS compounds are detected most frequently and at the highest concentrations in the shallow A zone and B aquifer and closer to known areas of PFAS use.
- The number of detections and the magnitude of detections tend to decrease with depth and distance from process areas.
- Detections are lowest along the perimeter wells and in deeper aquifers.

These trends are consistent with the source of PFAS at process buildings and former process waste culverts and wood-lined ditches from which process waters might originate and then migrate downward.

Although PFAS has been detected in on-site groundwater at concentrations that consistently exceed screening criteria for PFOA and PFNA, groundwater underlying the manufacturing area is contained by the operation of the IWS and the perimeter SPB (see Section 2.4). Potential and confirmed groundwater migration pathways are discussed further in Section 5.

4.2.3 Permitted Outfalls

Chambers Works has two permitted outfalls, DSN001 and DSN002, which convey treated WWTP wastewater mixed with non-contact cooling water and stormwater to a diffuser pipe located in the Delaware River, as shown in Figure 6. Since 2005, effluent monitoring samples from the WWTP are collected from location DSN662 on a weekly basis and analyzed for PFOA as part of the site NJPDES permit (see Tables 6a and 6b and Figure 7). From 2005 to present, the results of the NJPDES sampling, which includes the PFOA results, are reported by the site to EPA and NJDEP on a monthly basis. In addition, from 2005 through 2014, the permitted outfall PFOA results were submitted to EPA/NJDEP as part of the annual report *Status Report on PFOA Surface Water Emissions, Reductions, and Data Summary*; the references associated with the 2007 and the 2014 reports are noted in the reference section (DuPont CRG 2008a; AECOM 2015).

In addition to the weekly effluent permit samples, during a 15-month period from 2015 to 2017, outfall samples were collected on a monthly basis from DSN662 and analyzed for PFNA per agency request. PFNA results are posted in Table 6c. The results of the 15 monthly PFNA samples, along with associated PFOA results, were reported to EPA and NJDEP as part of the site's permit reporting process.

As part of the 2003 PFOA investigation (DuPont, 2003), outfall DSN001 was sampled for PFOA. At that time, the average PFOA detection was approximately 133 µg/L, and the outfall flow was recorded to be approximately 11 mgd. Using these values, a mass loading rate of 12 pounds per day (lbs/day) is calculated. Similar calculations using data collected from 2006 to 2014 indicate that PFOA loadings have decreased from 7 lbs/day in 2006 to less than 1 lbs/day in 2014 (see Table 6a). Results of regular outfall sampling have been tabulated and are provided in Table 6b and as a chart in Figure 7. Since 2000, a greater than 95% reduction of PFOA in the effluent discharge has been attained based on production estimates (Andrew Hartten, personal communication, June 22, 2017). These reductions are attributed to the PFAS load reduction programs implemented at the site, including the elimination of PFAS-containing waste streams managed at the WWTP, the installation of carbon treatment, and the manufacturing change to shorter chain PFAS.

4.2.4 Stormwater Outfalls

At Chambers Works, most rainfall is captured and transferred to the B Basin. From there, it is mixed with treated wastewater and discharged to the Delaware River. Rainfall not captured by the site sewer system can flow to adjoining surface water by means of grates and outfalls. A one-time sampling event was performed in April 2007 to determine the concentrations of PFAS at stormwater outfalls during a rainfall event. The results were reported via the *Status Report on PFOA Surface Water Emissions, Reductions, and Data Summary* (DuPont CRG, 2008a) and are shown in Figure 8 and in Table 7.

Several PFAS were detected during this one-time sampling event. The highest PFAS detected were perfluorohexanoic acid (PFHxA) and PFOA at Salem Canal outfall 07 (1.7 and 1.1 µg/L, respectively). Perfluoropentanoic acid (PFPeA) was the next highest (0.76 µg/L) at outfall SW003. Other PFAS detected were generally half that of the three highest PFAS compounds. These detections are believed to be due to the transport of PFAS in air emissions, or from general use and handling of PFAS at the site. These sources of PFAS may have migrated from paved areas and other catchment areas near the manufacturing areas to stormwater grates and outfalls during rainfall events.

4.2.5 Air Emissions

PFAS-containing air emissions, which are released through stacks and vents, have been generated as part of handling, processing, and disposal activities at Chambers Works. Air emissions containing PFAS were measured and reported in the 2003 report *DuPont Telomer Manufacturing Environmental Assessment of PFOA*. Based on that report, the loading of PFOA is estimated³ to have been about 0.79 lbs/day at Building 1163 and 0.001 lbs/day at Building 1156 (see Figure 9 for stack locations). Subsequent air emissions measurements were made for PFOA and other PFAS at Buildings 1156 and 1163 (see Table 8). In 2007, loading from Building 1156 was estimated to be 0.00017 lbs/day (DuPont CRG, 2008a). In 2008, PFOA loading from Building 1163 was estimated to be 0.024 lbs/day (DuPont CRG, 2008a). These data show that PFOA loadings vary depending on location at the site. However, the air emissions loading appear to have decreased over time due to the PFAS load reduction programs described in Section 3.4.

4.3 Off-Site PFAS Data

This section presents the results of previous off-site investigations of PFAS in various media. Off-site media investigated included the following:

- Delaware River surface water and sediment
- Salem Canal surface water and sediment
- Groundwater
- Residential drinking water

Results are presented in tabular form (see Tables 8 through 12) as well as on posting maps and figures (see Figures 9 through 18).

³ Estimated for this report based on Average Annual Emission Rate (DuPont CRG, 2003, Table 5) per hour and 8,760 hours per year.

4.3.1 Delaware River Surface Water and Sediment

Surface Water

Thirty surface water samples for PFOA were collected from the Delaware River as part of the 2003 Environmental Assessment (DuPont, 2003). The purpose of this sampling was to characterize the background, near field, and far field concentrations of PFOA in relation to outfall DSN001 in the Delaware River. These samples were collected offshore of Chambers Works, as well as several miles upstream and downstream of the Chambers Works site (see Figure 10).

The 12 samples collected upstream of the site were all ND for PFAS. Six samples were collected adjacent to the site: three samples collected on the western side of the river were NQ⁴ while the three samples closest to the site ranged from 0.154 µg/L to 0.566 µg/L. The 12 samples collected downstream of the site ranged from NQ to 0.301 µg/L. The data show that upstream concentrations were ND, concentrations on the eastern side of the river were higher than the western side of the river, and concentrations measured near the site decreased downstream of the site.

Sediment

Two sampling events investigated the presence of PFAS in sediment within the Delaware River. Sediment samples for PFOA were collected at 19 stations along the western perimeter of Chambers Works in the Delaware River in 2013 (URS, 2013a). In addition, in 2016, 12 sediment samples from six locations were also collected for analysis of 16 PFAS compounds (AECOM, 2017b). The locations of these samples, along with associated summary data posting tables, are shown in Figure 11, and the results are presented in Table 9.

In the 2013 sampling, PFOA was not detected in any shallow (0 to 0.5 feet) sediment sample except for DER1-13, DER1-15, and DER1-16, which are within the vicinity of the permitted outfall DSN001. Detections were highest south of the outfall at DER1-13 [60 micrograms per kilogram (µg/kg)] and lower north of the outfall at DER1-15 and DER1-16 (5.2 and 21 µg/kg, respectively). No detections of PFOA were recorded further upstream or downstream of the permitted outfall.

In the 2016 investigation, PFOA had the greatest number of detections (eight out of 12 samples). However, PFHxA had the highest detection (40 µg/kg) and the highest average detection (9.87 µg/kg). Detections of PFHxA, PFOA, and perfluorodecanoic acid (PFDA) were generally three times higher than the other PFAS samples.

The Delaware River surface water and sediment samples indicated the presence of PFAS adjacent to the site manufacturing area. The 2013 PFAS detections in sediment adjacent to and down river from outfall DSN001 indicate that the outfall is a likely source. The 2016 Delaware River sediment samples also indicate the presence of PFAS in sediment and that the samples from the deeper interval (0.5 to 1 foot) had the higher number of PFAS detections and higher concentrations as compared to the shallower 0 to 0.5-foot interval.

⁴ Not Quantifiable = detected at a concentration between the limit of detection and the limit of quantification as indicated in the associated tables and figures, as appropriate.

4.3.2 Salem Canal Surface Water and Sediment

Surface Water

In February 2007, surface water samples for PFOA and 14 other PFAS were collected from nine locations to investigate PFAS in the Salem Canal, Salem Creek, and Clemente Pond (see Figure 12). The purpose of this investigation was to characterize the Salem Creek Watershed upstream of the site with respect to PFAS (DuPont CRG, 2007b). PFOA was detected in each upstream sample location (see Table 10). PFOA concentrations ranged from 0.017 µg/L to 1.100 µg/L, and generally decreased with distance upstream.

In 2016, 12 surface water samples for PFAS were collected from Salem Canal as part of the 2016 Salem Canal Investigation. The purpose of the canal-wide characterization was to evaluate whether Salem Canal sediments had been impacted by releases from past Chambers Works operations in general, and from the historical and/or current outfalls along the Chambers Works Complex in particular (AECOM and EHS Support, 2017). The locations of these surface water samples, collected at the surface water to sediment interface, are also shown in Figure 12.

Results from the 2016 sampling event indicate the presence of several PFAS. Five PFAS [PFBA, perfluoroheptanoic acid (PFHpA), PFHxA, PFPeA, and PFOA] were detected in each surface water sampling station. However, concentrations detected were typically low (0.05 µg/L; see Table 10) and showed little variation in concentration from the background detections upstream of the site to the confluence below the dam and into the Delaware River. As a result, it appears that Chambers Works is not contributing to changing PFAS characteristics as surface water moves across the southern portion of the Chambers Works site.

Sediment

Sediment samples from Salem Canal were also collected during the aforementioned 2016 Salem Canal Investigation. This investigation included the collection of 49 sediment samples from 16 stations in Salem Canal. Ten stations were located adjacent to existing and historical outfalls. Four stations were distributed in the center of the channel and near the south shore. The remaining two stations were collected upstream of the Chambers Works site in a reference area. Sediment sample locations are detailed in Figure 13.

Previous studies of Salem Canal have determined that the sedimentation rate associated with this canal is approximately 1 centimeter (0.39 inches) per year (AECOM and EHS Support, 2017). One foot of sediment equates to approximately 30 years of sedimentation. Therefore, to evaluate vertical changes in PFAS characteristics, vertically oriented samples were collected during the 2016 investigation to a depth of up to 3 feet in half foot intervals at six of the stations. Analytical results for sediment samples are summarized in Table 11 and detailed in figures provided in Appendix B.

As detailed in Table 11 and shown in the Appendix B figures, PFAS are detected within the sediments of the Salem Canal. PFAS was detected in samples collected both upstream and adjacent to the site. The upstream detections of PFAS within canal sediment indicate the potential impact to upstream sediment by an off-site PFAS source.

Most PFAS sediment detections along Salem Canal were low and slightly above laboratory practical quantitation limits (PQLs). The highest detections of PFAS were observed at sediment sampling stations SCD-189 and SCD-236, which are adjacent to

current or historical outfalls. The distribution of PFAS compounds is generally similar within each sediment sample at these stations, e.g. SCD-189 (see Figure 14). However, at SCD-189, the summed total concentration of PFAS decreases from a high of approximately 112 µg/kg at a depth of 1.5 to 2 feet to a low of approximately 16 µg/kg in the 0 to 0.5-foot interval. This decrease in concentration with decreasing depth of the sample within the top few feet of sediment is likely associated with the PFAS reduction programs that were enacted at the site.

4.3.3 Groundwater

Several off-site investigations were conducted between 2007 and 2014 to better understand the distribution of PFOA and other PFAS in the groundwater surrounding the site.

Initially, nine permanent monitoring wells (five on-site⁵ and four off-site) were installed in October 2007 in the shallow A zone and were sampled in November 2007 for PFOA and other PFAS as described in the *Perfluorooctanoic Acid (PFOA) Quality Assurance Project Plan with Sampling and Analysis Plan* (DuPont CRG, 2007c).

Following NJDEP's review of the November 2007 sampling results, NJDEP requested the installation of an additional eight monitoring wells in the surrounding community in a letter dated August 21, 2008. The objective of the investigation was to confirm the findings of the 2007 sampling effort and to better understand the distribution of PFAS in off-site groundwater and groundwater flow directions in the shallow aquifer. As a result, in January 2009, four off-site monitoring wells were installed in the A zone (BB31-M01A, EE16-M01A, R04-M01A, and U08-M01A), and four off-site monitoring wells were installed in the B aquifer (BB31-M01B, EE16-M01B, OSW-1, and R04-M01B). Groundwater was then sampled for PFAS in February 2009 from the eight newly installed off-site locations and nine locations previously sampled in November 2007.

Based on the findings of the 2009 investigation, NJDEP requested the installation of three additional wells in a letter dated September 23, 2009. As a result, in October 2010, three off-site monitoring wells were installed in the A zone (OSW-2, OSW-3, and OSW-4). Groundwater was then sampled for PFAS in November 2010 from the three newly installed off-site locations and 17 locations previously sampled in February 2009.

In a letter dated April 23, 2014, EPA Region 2 then requested an additional round groundwater sampling to evaluate temporal trends at all of the 20 monitoring well locations previously sampled as part of the prior off-site monitoring events. As a result, groundwater was sampled in July 2014 for PFOA plus 12 additional PFAS compounds.

To obtain updated off-site well data, nine of the 20 wells sampled in 2010 and 2014 were resampled in 2016: OSW-1, OSW-2, OSW-3, OSW-4, EE16-M01A, EE16-M01B, II20-M01A, R04-M01A, and R04-M04B. The groundwater samples collected were analyzed for PFOA plus 12 additional PFAS compounds.

The analytical data collected during these five sampling events (2007, 2009, 2010, 2014, and 2016) indicated that PFAS are present in the groundwater in the areas investigated

⁵ These five eastern and southern site boundary locations (Y31-M01A, X18-M01A, U08-M01A, O02-M01A, and G04-M01A) were installed on-site inside the site security fence. For consistency with prior reporting, data from these boundary locations are discussed along with the monitoring wells installed off-site outside of the security fence.

at varying concentrations and that, due to containment by the site IWS, groundwater flow is generally towards the site from the off-site locations. As detailed in Table 12:

- Groundwater PFOA concentrations ranged from NQ to 3.6 µg/L in the 20 wells sampled. The highest detection for PFOA was consistently reported at well X18-M01A, which is an eastern boundary location within the site security fence. PFOA concentrations in the off-site locations ranged from NQ to 1.5 µg/L.
- PFOS concentrations ranged between NQ and 0.046 µg/L.
- With the exception of off-site location CC23-M01A, concentrations of PFOA or the sum of PFOA and PFOS were detected above the EPA HA of 0.07 µg/L in each location sampled.
- PFNA concentrations ranged between 0.0014 µg/L and 0.36 µg/L. PFNA detections above the NJGWIIA criteria of 0.01 µg/L were observed in off-site locations northeast and southeast of the site.
- The concentrations of the other PFAS ranged from ND (< 0.0008 µg/L) to 2.9 µg/L.
- A review of the off-site well data did not identify any definitive concentration trends.

In addition to the off-site well data presented in Table 12, Figure 15 identifies the location of the 20 off-site monitoring wells and posts the latest data set (2014 or 2016) associated with each well.

4.3.4 Residential Drinking Water Wells

2009 Sampling

In 2009, Chemours (formerly DuPont) agreed to institute a voluntary program to evaluate private drinking water wells within a two-mile radius of the Chambers Works site. The purpose of this program was to evaluate the distribution of PFOA in off-site residential wells. As part of this study, residential well owners were given the opportunity to have their drinking water well tested. If agreed to, a drinking water sample was collected from an untreated faucet and submitted for PFOA analysis. The program included sampling of 113 private drinking water wells.

Of the 113 drinking water wells sampled, only one private well contained a PFOA concentration greater than EPA's 2009 Provisional Health Advisory Level (0.4 µg/L). A granular activated carbon (GAC) treatment system was installed, and quarterly operation, maintenance and monitoring (OM&M) are conducted to ensure the effectiveness of the GAC system.

2016 Sampling

Based on an agreement with EPA and NJDEP, re-sampling of off-site residential wells was initiated by Chemours in 2016 to determine the extent of impact to residential wells surrounding the Chambers Works Complex and to verify the findings of the previous sampling program. This new round of sampling evaluated residential drinking water wells for PFAS, with emphasis on PFOA, PFNA, and PFOS. The program was initiated using a phased approach. As results became available and additional sampling locations were identified, a figure was created to visually determine the extent of detections (see Figure 16). Figure 16 also provides the results of the 2009 sampling. Because this

program is ongoing, this summary only discusses information available through April 26, 2017.

Sample results were compared to the screening values as described in Section 4.1. Forty-eight drinking water wells were qualified for treatment. Each drinking water well owner was offered treatment by Chemours to remediate drinking water and eliminate potential drinking water exposure. Forty-seven residents with drinking water wells that qualified for treatment have accepted the treatment offer and either had a GAC filter installed or have been connected to public water. Each GAC system has been included in the ongoing quarterly OM&M. One resident with a drinking water well that qualified for treatment has declined treatment. Results of the residential sampling program through April 26, 2017 for all PFAS are provided in Appendix A and shown in Figure 16 for PFOA, PFOS, and PFNA.

An evaluation of the most recent data collected as part of the off-site B groundwater investigation (see Section 4.3.3 above) and that collected as part of the 2016 residential sampling program shows that PFOA was one of the most frequently detected PFAS and also had some of the highest detections. When the concentration of PFOA is graphed in relation to the distance of the sample point from the center of the Chambers Works site (see Figure 17), a general decreasing trend is observed moving away from the site. However, a similar trend is not as obvious when the PFOA data are plotted with respect to their location in relation to the Chambers Works site and the prevailing wind direction (see Figure 18). Although the trend data are suggestive of downwind transport from a source area, the spatial distribution of concentrations does not appear to be solely controlled by distance from the site and frequent prevailing wind directions. For example, wells may have widely differing PFAS concentrations despite close proximity to one another and a location that is downwind of the site. It is possible that other factors, including other PFAS sources, differences in well-construction/well-depth, or impermeable pavement account for the observed variability within the residential drinking water data set.

The variation in PFOA occurrence and magnitude of concentration in off-site residential wells as shown in Figure 18 does indicate the potential that the Chambers Works site is not the sole source for all observed off-site PFAS detections in groundwater. This conclusion is supported by the plot of PFOS well data in relation to its spatial distribution around Chambers Works (see Figure 19). PFOS is not a PFAS used at the Chambers Works site nor is it a breakdown product of other PFAS used at the site. Figure 19 shows that PFOS groundwater detections on and adjacent to Chambers Works are either low or below detection limit. However, a large PFOS detection was obtained in an off-site residential well located approximately 2 miles northeast of the site manufacturing area. The residential PFOS detection could be due to the use of household products on the property such as cleaning products and/or pesticides, or the PFOS detection could be due to a nearby source unrelated to the Chambers Works site. Based on the low PFOS detections between this residential property and the site, it is highly unlikely that the PFOS residential well detection is associated with Chambers Works.

4.4 Summary of PFAS in On-Site and Off-Site Environmental Data

Sampling of various media for laboratory analysis for PFAS has been conducted at and around the Chambers Works site as early as 2000. Over the past 15-plus years, PFAS laboratory analytical samples have been collected from multiple media including the following:

- Soil
- Groundwater (on and off-site)
- Surface water
- Sediment
- Outfalls
- Air emissions

A summary of the pertinent PFAS samples collected for each media, and the associated number of PFAS analyzed for each sample, can be found in Appendix C. Overall, the environmental data collected to date provide an adequate characterization and understanding of these media that is necessary to develop a conceptual site model. A summary of the PFAS analytical results and associated findings presented in this section is as follows:

- PFAS have been detected in soil and groundwater at the Chambers Works Complex. PFAS compounds are detected most frequently and at the highest concentrations in shallow groundwater samples closest to known process areas that used PFAS and decrease with increasing depth and distance from known process buildings.
- Past investigations have documented PFAS in surface water and sediment in the Salem Canal and Delaware River. Upstream detections of PFAS in Salem Canal could be associated with the deposition of air emissions from the site, or could indicate the potential for impact to the canal by an off-site PFAS source. However, the proximity of the higher PFAS sediment detections to the permitted outfalls and stormwater outfalls coincides with discharge from plant effluent and stormwater runoff.
- Elevated PFAS concentrations in deeper sediment and lower concentrations in shallower sediment can likely be attributed to reductions in sources.
- Off-site groundwater investigations in 2007, 2009, 2010, 2014, and 2016 as well as an on-going residential drinking water well sampling program indicate the presence of PFAS in off-site groundwater and drinking water.
- Remediation of drinking water is ongoing and includes the installation and OM&M of GAC treatment systems or connection to a public water supply, where possible, for off-site drinking water wells that exceed the applicable criteria.
- Spatial variability in off-site groundwater and drinking water concentrations suggest that factors other than distance from the site may influence PFOA and other PFAS concentrations. The distribution of PFOS concentrations supports the conclusion that the Chambers Works site is not the sole source for all observed off-site PFAS detections.

5.0 PFAS Migration Pathways

PFAS data collected in and around the Chambers Works Complex over approximately 15 years provide an adequate characterization and understanding of these compounds in the various media that is needed in order to develop a conceptual site model. On-site sources of PFAS at Chambers Works and off-site sources unrelated to Chambers Works were identified in Section 3.0. PFAS detections in various media were assessed to determine PFAS distribution on- and off-site as presented in Section 4.0. This section describes PFAS migration pathways from on-site sources to on- and off-site environmental media. A discussion of potential off-site sources and associated migration pathways is also provided.

5.1 On-Site and Off-site Migration Pathways for On-Site Sources

The conceptual model shown in Figure 20 depicts the known and potential on-site PFAS sources and the migration pathways from those sources to on- and off-site environmental media. These sources and migration pathways are identified in Table 13 using letters A through G and are depicted in Figure 20. Sources in Table 13 include both sources where PFAS material can originate as well as media that can act as a secondary source. These sources and migration pathways are as follows:

- (A) Treated wastewater effluent discharging from the WWTP to off-site surface water and sediment in the Delaware River.
- (B) Process building stack and vent air emissions that transport PFAS and fluorotelomer alcohol from sources inside process buildings to the atmosphere and then downwind. PFAS and precursor compounds can then be deposited onto on- and off-site surfaces (e.g., gravel, concrete, or asphalt), soil and/or surface water. Soils can then be a secondary source of PFAS where precursor compounds such as fluorotelomer alcohol breaks down to PFAS, which may then infiltrate and leach to underlying shallow groundwater.
- (C) During precipitation events, runoff from surfaces or runoff or erosion of PFAS-containing soil (because of air deposition or direct releases to soil) can migrate to on- and off-site site surface water and sediment such as Henby and Bouttown Creeks, or the Salem Canal or Delaware River via stormwater outfalls.
- (D) Direct releases to soil as the result of spills during storage, handling, or manufacturing; or during the transport of PFAS-containing waste materials in wood-lined culverts or ditches. Soils are then a secondary source of PFAS, which may then infiltrate and leach to underlying shallow groundwater.
- (E) Direct releases to soil or air from PFAS-containing WWTP sludge placed in the on-site landfill. Soils are then a secondary source of PFAS, which may then infiltrate and leach to underlying shallow groundwater.
- (F) PFAS-containing shallow A zone and/or B aquifer groundwater discharging to surface water and sediment (such as the Salem Canal or Delaware River).
- (G) PFAS from off-site surface water or sediments from migration pathway (A) (secondary source) infiltrating back into on-site groundwater.

5.1.1 Effluent Discharge (A)

The discharge of PFAS in treated process wastewater effluent from the WWTP to surface water and sediment in the Delaware River is a confirmed migration pathway. Process wastewater is collected in regional sumps and conveyed to the WWTP for treatment. Final effluent is mixed with non-contact cooling water and storm water before it is discharged to the Delaware River through permitted outfalls. Programs have been in place since 2004 to reduce emissions of PFAS. To monitor this migration pathway, effluent from the WWTP has been and continues to be sampled to characterize loading of PFAS, in particular PFOA, to the Delaware River. As discussed in Section 4.2.3, PFOA loading as a result of effluent discharge has decreased in response to site programs to reduce PFAS in emissions.

5.1.2 Air Emissions (B)

Process building stack and vent air emissions discharging PFAS to the atmosphere, which is then transported via dispersion and deposition to on- and off-site surfaces, soil and surface water, are a confirmed migration pathway. Releases due to the handling and processing of fluorotelomer and fluoroelastomer related products and intermediates create the potential for the movement of PFAS out of process stacks and vents. From there, these constituents can move downwind and be deposited on surfaces. As part of this migration pathway, soils, where precursor compounds can breakdown to PFAS, may then act as a secondary source from which PFAS may infiltrate and leach to underlying shallow groundwater during precipitation or migrate to surface water bodies via stormwater run-off. As discussed in Section 4.2.5, PFOA loading because of air emissions has decreased in response to site programs to reduce PFAS in emissions.

PFAS-containing air emission can also migrate to off-site soils and then to off-site groundwater, which is a drinking water source. Off-site drinking water wells have been sampled and 48 drinking water wells were qualified for treatment (see Section 4.3.4). Each drinking water well owner was offered treatment by Chemours to remediate drinking water and address potential drinking water exposure. Forty-seven residents with drinking water wells that qualified for treatment have accepted the treatment offer and had a GAC filter installed or have been connected to public water. Each GAC system has also been included in the ongoing quarterly OM&M program.

5.1.3 Stormwater Runoff (C)

During precipitation events, runoff from surfaces or runoff or erosion of PFAS-containing soil (because of air deposition or direct releases) via stormwater outfall discharge to off-site surface water and sediment (Salem Canal or Delaware River) is a confirmed migration pathway. Stormwater runoff is either 1) captured by the site stormwater system and transferred to the B Basin for storage prior to being discharged to the Delaware River; or 2) flows directly off-site via outfalls to the Salem Canal or Delaware River. PFAS has been detected in stormwater flowing from outfalls during a rainfall event (DuPont CRG, 2008a). In addition, PFAS has been detected in surface water and sediment of the Salem Canal. An assessment of surface water results determined that surface water PFAS concentrations were generally comparable throughout the Salem Canal, including upgradient of the site, and that upstream detections of PFAS in Salem Canal indicate the potential for impact to the canal by other off-site PFAS sources.

In sediment, elevated PFAS concentrations at depth and lower concentrations in the shallow sediment sampling depths (i.e., within the top few feet) were associated with two

sediment sampling stations (SCD-189 and SCD-236) located next to two stormwater outfalls (see Section 4.3.2). The pattern of lower concentrations in the shallow depth with increasing concentrations with depth may likely be attributed to the PFAS reduction programs that were enacted at the site. Thus, lower concentrations would be expected in the surficial sediment.

5.1.4 Direct Releases to Soil (D and E)

Direct releases to soil include spills and discharge from source processes (D) and the landfilling of PFAS-containing wastes from the WWTP (E). There were no documented spills of PFAS. Prior to 1970, process liquids were conveyed to the WWTP for treatment by means of a series of interconnected culverts and wood-lined ditches. Seepage from these features could have resulted in the movement of PFAS into soil and groundwater on site. This migration pathway was complete prior to the installation of the site's elevated liquid waste system in 1991 and the improvements in PFAS handling in the 1990s and onward. Although this soil to groundwater PFAS migration pathway is still a possibility, groundwater flow is largely controlled at the site by means of the IWS and the installed SPB. Therefore, there is no migration pathway from a release to soil to off-site well locations (see Section 2.4).

5.1.5 Groundwater Discharge (F and G)

The discharge of PFAS-containing shallow A zone and B aquifer groundwater to off-site surface water and sediment (F) is controlled by the installed SPB (see Section 2.4). Based on groundwater flow balance calculations presented in the 2014 RFI report and measurements of PFOA from on-site wells along the western perimeter, the discharge of on-site groundwater to off-site surface water was estimated to be less than 2 grams per day. Once installation of the final section of SPB is completed in 2017, shallow aquifer flow underlying the manufacturing area will be fully controlled at the site and the groundwater-to-surface water discharge pathway will be incomplete.

Chambers Works maintains control of C and D aquifer groundwater by means of pumping of the IWS. Therefore, groundwater is not a viable migration pathway for the movement of PFAS to off-site well locations.

5.2 Off-Site Migration Pathways for Off-Site Sources

As previously discussed in Section 3.4, the use and disposal of PFAS-containing products at off-site locations could be potential sources that result in releases of PFAS to the environment that are unrelated to Chambers Works. The conceptual model shown in Figure 21 depicts five potential off-site PFAS sources migration pathways. These sources and migration pathways are described on Table 14 and include the following:

- (1) Industrial, agricultural, landfilling, and anthropomorphic processes that use PFAS containing materials can result in the release of vapors, aerosols, and particulates. These air emissions may then be transported via dispersion and deposited to off-site as well as on-site surfaces, soil and surface water. Subsequent rainfall can dissolve or entrain these constituents, which can then migrate into soil or surface water and eventually migrate into groundwater.
- (2) Discharge of PFAS impacted groundwater to surface water. This discharge can result in the movement of dissolved constituents from upgradient sources to downgradient surface water.

- (3) Surface water may infiltrate into and recharge underlying aquifers, particularly in areas where groundwater pumping has drawn the groundwater surface elevation to below that of the surface water elevation. If the surface water contains PFAS, this can introduce PFAS into groundwater.
- (4) PFAS containing groundwater may be drawn into wells during pumping.
- (5) PFAS may enter household graywater due to the use of PFAS containing products that can then enter the waste stream. PFAS-containing graywater may then migrate from septic tank leachate fields to surrounding soils and underlying shallow groundwater (Schneider 2016; Silentsprings.org article).

6.0 Summary

This CSM represents the current understanding of PFAS sources, migration pathways, and the on-site and off-site environmental media, which have been impacted by on-site sources. The purpose of this CSM was to provide a written and illustrative representation of the potential fate and transport of PFAS from on-site sources to on-site and off-site media. The areal scope of the CSM includes the Chambers Works Complex, the adjoining Delaware River, and surrounding off-site areas. Processes that used PFAS at Chambers Works were identified based on current and historical information. Results of ongoing and past PFAS investigations adequately characterize PFAS concentrations in environmental media on-site and off-site as well as in air emissions from site processes and water discharge from the permitted outfalls. A summary of the CSM components discussed within this report is provided in the following sections.

6.1 PFAS Sources

PFAS and precursors to PFAS (i.e., fluorotelomer alcohols) have been used in the production of fluoroelastomers, fluorotelomers, and have also been unintentionally created within manufacturing processes and waste streams at Chambers Works. In addition, PFAS were also contained in off-site waste brought to Chambers Works for treatment and disposal by the site. These processes and activities have been identified as potential sources of PFAS at Chambers Works.

6.2 Migration Pathways from PFAS Sources

Based on the use and manufacturing history, the following known or potential migration pathways from PFAS sources have been identified:

- PFAS transported by air emissions from sources, through stacks and vents, and then downwind during manufacturing or handling activities and deposited on surfaces, soils and surface water.
- Releases of fluorotelomer alcohols, which can deposit onto downwind soils and react in the environment and produce PFAS.
- Spills of PFAS-containing materials during storage, handling, and/or manufacturing processes (although none were documented).
- Releases of PFAS-containing wastes to soil during conveyance to the WWTP through culverts and wood-lined ditches, which can then leach and migrate to groundwater. However, groundwater flow is controlled at the site, and there is no migration pathway to off-site groundwater.
- PFAS-containing effluent discharges from the WWTP to surface water due to the treatment of PFAS-containing wastes.
- PFAS-containing sludge from the WWTP disposed of in the on-site landfill, which can then leach and migrate to groundwater. However, groundwater flow is controlled at the site, and there is no migration pathway to off-site groundwater.
- During precipitation events, runoff from surfaces or runoff or erosion of PFAS-containing soil (because of air deposition or direct releases) to off-site surface water and sediment (Salem Canal or Delaware River) via stormwater outfalls.

Since 2000, PFOA/PFAS emissions (air and effluent) at the site have declined 99%. These reductions decrease the availability of PFAS in on-site sources to migrate to environmental media.

The off-site use and disposal of PFAS-containing products unrelated to Chambers Works could also act as potential off-site PFAS sources. While specific off-site sources have not been identified, these sources may contribute to the PFAS detected in off-site environmental media, as well as on-site media (i.e., Salem Canal surface water).

6.3 PFAS Distributions in On-Site and Off-Site Environmental Media

Previous sampling programs have measured PFAS in stack and vent air emissions, WWTP effluent discharge at permitted outfalls, and in stormwater outfalls. PFAS have also been characterized in soil and groundwater at the Chambers Works Complex. PFAS compounds were detected most frequently and at the highest concentrations in shallow groundwater samples closest to known process areas that used PFAS and decreased with increasing depth and distance from known process buildings.

Past investigations have documented PFAS in off-site surface water and sediment in the Salem Canal and Delaware River. The proximity of the detections to the permitted outfalls and stormwater outfalls is consistent with WWTP effluent discharge and stormwater runoff. Elevated PFAS concentrations in deeper sediment and lower concentrations in shallower sediment likely reflect the success of the efforts to reduce the use of PFAS at the site that would be expected to result in lower PFAS concentrations in surficial (more recent) sediment samples.

Off-site groundwater investigations in 2007, 2009, 2010, 2014, and 2016, as well as an on-going residential drinking water well program, indicate the presence of PFAS in off-site groundwater and drinking water. Forty-eight drinking water wells were qualified for treatment and each drinking water well owner was offered treatment by Chemours to remediate drinking water and address potential drinking water exposure. Forty-seven of these residents have accepted the treatment offer and had a GAC filter installed or have been connected to public water. Each GAC system has also been included in the ongoing quarterly OM&M program.

Some of the residential well detections are believed to be due to air transport of PFAS to downwind locations because there is no migration pathway through groundwater to off-site groundwater locations. The concentration of PFOA in off-site samples tends to decrease with increasing distance from the site. However, the spatial variability on off-site groundwater concentrations, as well as the detections of PFAS unrelated to the site (PFOS), suggests that factors other than distance from the site, including potential off-site PFAS sources, may influence PFOA and other PFAS concentrations in groundwater.

Off-site groundwater investigations in 2007, 2009, 2010, 2014, and 2016, as well as an ongoing residential drinking water well program, indicate the presence of PFAS in off-site groundwater, at times exceeding NJDEP and/or EPA criteria for PFOA, perfluorooctane sulfonate (PFOS), or perfluorononanoic acid (PFNA). While air emissions from the site contribute to these detections, off-site sources of PFAS unrelated to the site may also add to these detections as the variability in PFAS constituents detected and the variable nature of the observed concentrations does not support a single point of origin in all cases. However, Chemours is actively working with NJDEP and EPA to continue to investigate, and remediate and address potential

drinking water exposure by offering to treat off-site drinking water for PFAS if criteria are exceeded.

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